Impacts of Natural and Forced Climate Variability on the Gulf of Mexico

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Introduction

According to our previous study (Liu et al. 2012), the volume transport by the Loop Current (LC) can be reduced by 20 - 25% at the end of 21st century. The reduced LC and the associated weakening of the warm LC eddy may have a large cooling impact in the GoM, particularly in the northern basin, and thus have strong impacts on the marine ecosystem in the GoM. Here, we further confirmed our conclusion using a high-resolution ocean model constrained with the surface forcing fields, initial and boundary conditions obtained from the CMIP5 model simulations under RCP4.5 and RCP8.5 scenarios (Fig 1, 2 and 3).

The downscaled ocean model results indicate that the sea surface temperature (SST) in the GoM may increase by more than 1.5^{o}C at the end of the 21st century. The observed SST in the GoM during the 20th century shows long-term SST variability consistent with the Atlantic Multidecadal Oscillation. The amplitude of this multi-decadal signal is as large as 0.5^{o}C, which is comparable to the Anthropogenic greenhouse warming (AGW)-induced SST increase in the GoM by the 2030s. This means that the AGW-induced SST increase in the GoM can be doubled or nearly canceled out due to natural variability. Therefore, to further explore the impact of natural climate variability on the forced response of the GoM, here we perform dynamic downscaling of the surface-forced global ocean model simulation to the GoM region for the period of 1871-2008 (Fig 4 and 5). The potential implications of natural and forced thermal changes in the northern GoM on pelagic fish species and their spawning patterns will be further studied in the future.

Model Experiments

Ocean model: GFDL Modular Ocean Model (MOM4p1)

Domains: Atlantic Ocean (20°S – 65°N)

Horizontal grid: High resolution (0.1° in GOM, 0.25°elsewhere),

Vertical: 25 vertical depth coordinate layers

1. Force Climate Variability Run

Surface forcing: Ensemble weighted **CMIP5** atmospheric forcing with bias correction.

IC & BC: CMIP5 salinity and temperature with bias correction

Run periods (high resolution):

- Late 20C run: 1981-2000 for Historical Scenario
- Mid 21C run: 2041-2060 for RCP4.5 & RCP8.5
- Late 21C run: 2081-2100 for RCP4.5 & RCP8.5

2. Natural Climate Variability Run

Surface forcing: 20th Century Reanalysis **(20CR)** surface flux

IC & BC: simple ocean data assimilation (**SODA v2.2.6)** salinity and temperature

Run periods (high resolution): from 1871-2008.

Impact of Forced Climate Variability

Fig. 1: RCP4.5

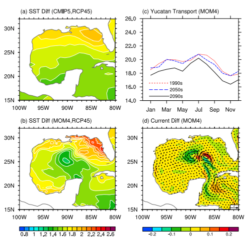


Fig. 2: RCP8.5

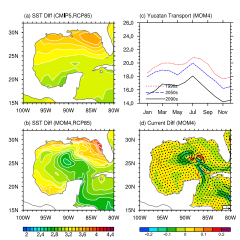
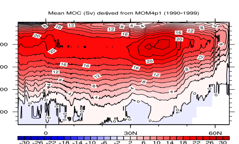


Fig. 1: SST difference between the late 21st century and late 20th century for AMJ season obtained from (a) CMIP5 models (low-resolution) and (b) MOM4 model (high-resolution) under RCP4.5 scenario. (c) Seasonal Yucatan Current transport for the three different periods (late-20th century, mid 21st century and late 21st century) from MOM4. (d) Surface current and current speed difference between the late 21st century and late 20th century for AMJ season from MOM4. Vectors indicate the current difference and contour shows the current speed difference.

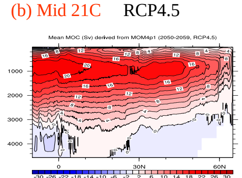
Fig. 2:Same as Fig. 1, except that the differences are from the CMIP5 RCP8.5 scenario. The color bar is different with that in Fig.1. SST increase is more severe under RCP8.5 scenario.

AMOC

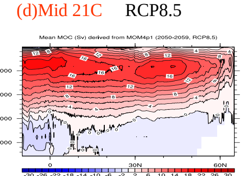
(a) Late 20C Historical Run



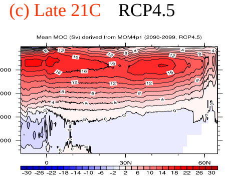
(b) Mid 21C RCP4.5



(d)Mid 21C RCP8.5



(c) Late 21C RCP4.5



(e) Late 21C RCP8.5

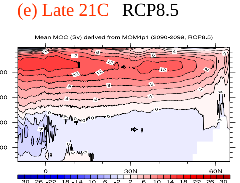


Fig. 3: Time-averaged Atlantic Meridional Overturning Circulation (AMOC) in (a) the late 20th century and (b) the mid 21th century and (c) late 21st century obtained from the downscaled MOM4 simulations under the RCP4.5 scenario. Figure (d) and (e) are same as (b) and (c), respectively, but under the RCP8.5 scenario.

Impact of Natural Climate Variability

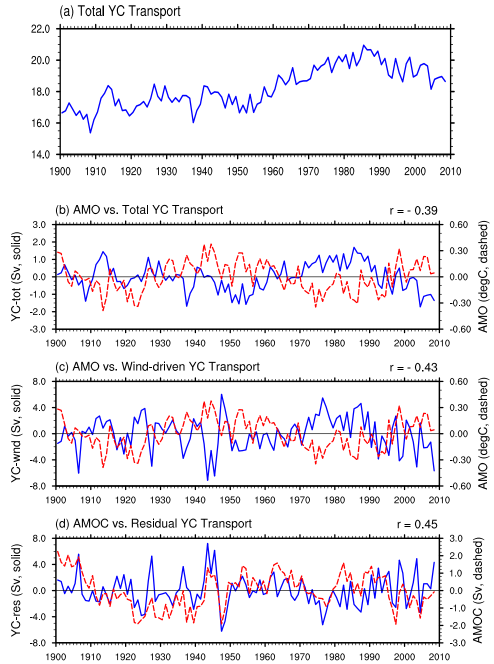


Fig 4 :(a) Time series of the total volume transport across Yucatan Channel; (b) Time series of the anomalous total YC transport (solid), together with the AMO index (dashed); (c) Time series of wind-driven component of YC transport (solid), together with the AMO index (dashed); and (d) Time series of the residual (total minus wind-driven component) of YC transport (solid), together with the AMOC index (dashed) during the 1871-2008 obtained from the MOM4 natural climate variability simulation output.

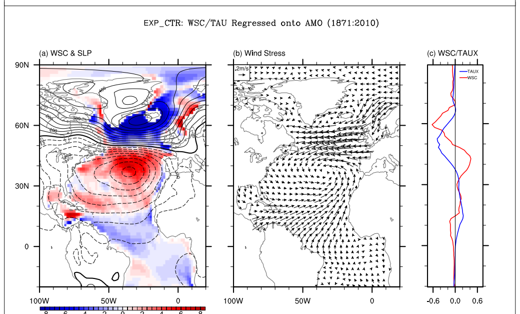


Fig 5 :(a) Monthly wind stress curl (color), sea level pressure (contour) and (b) wind stress (vector) regressed onto the AMO index from 1871 to 2010 periods, obtained from 20CR. (c) Zonally averaged wind stress (blue line) and wind stress curl (red line) from 1871 to 2010, obtained from 20CR.

Impact of Natural Climate Variability

Fig.5 clearly shows that co-variability of the North Atlantic SSTs and SLPs leads to reduced trades and westerlies in the North Atlantic during a positive AMO phase. The reduced trades and westerlies, in turn, produce a positive wind stress curl anomaly and anomalous Ekman divergence over the subtropical North Atlantic between about 15°N and 50°N. Together with the barotropic streamfunction response (not shown here), it shows that a positive phase AMO can lead to a weakening of the subtropical North Atlantic gyre circulation.

Conclusions

Downscaling CMIP5 climate models show that YC transport will be reduced during 21st century (under both RCP4.5 and RCP8.5 scenarios). This is associated with the slowing down of the AMOC.

The reduced LC and the associated weakening of the warm LC eddy have a cooling impact in the northern GoM. Due to this cooling influence, the northern GoM is characterized as the region of minimal warming. These results are consistent with the results using CMIP3 forcing.

Downscaled MOM4 model output shows that YC transport is wind-driven, as well as thermohaline-driven. The wind-driven part is dominant and is associated with AMO variation.

Wind-driven YC transport variability is highly anti-correlated with AMO. A positive phase of AMO is associated with a positive anomaly in wind stress curl in the subtropical region, and thus causes Ekman divergence and a reduced subtropical gyre circulation and the reduction of YC transport.

References:

Liu Y., S.-K. Lee, B. A. Muhling, J. T. Lamkin and D.B. Enfield, 2012: Significant reduction of the Loop Current in the 21st century and its impact on the Gulf of Mexico. J. Geophys. Res., 117, C05039, , doi:10.1029/2011JC007555

Muhling, B. A., S.-K. Lee, J. T. Lamkin and Y. Liu, 2011: Predicting the effects of climate change on bluefin tuna (Thunnus thynnus) Spawning habitat in the Gulf of Mexico. ICES J. Mar. Sci., doi:10.1093/icesjms/fsr008.

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